Swami Ramanand Teerth Marathwada University, Nanded

-: Name of the Research Topic: -

Development and Characterization of Nickel Oxide based nanostructured films for gas sensing application

Faculty of Science in the subject Physics

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Abstract of work plan: -

This study systematically investigates the nanostructure growth, optical and electrical properties of nickel oxide (NiO) films prepared via chemical method. Application of aluminium and nickel oxide in many fields particularly in solar energy conversion technology encourages us to study physical properties of material. The deposition of the thin films on the glass substrate using by spray pyrolysis using X-ray diffraction (XRD), UV-visible and scanning electron microscopy (SEM) spectrophotometry. different optical quantities such as optical band gap, refractive index, extinction coefficient, dielectric constant, volume, and surface energy loss function at the temperature 300^0c. The present-day study focusses on the synthesis of Fe doped NiO films by the method using the source of nickel acetate tetrahydrate and iron nitrate dehydrate. The prepared Fe doped Nio samples are characterized by x-ray diffraction, UV-visible spectroscopy, field emission scanning electron microscopy, transmission electron microscopy etc.

Introduction:

Material combining nano-crystallinity and nano-porosity can be exhibit interesting physical and chemical properties because of their large surface to value ratios and the possible existence of reason with high surface energy and phase composition different from those in the bulk. The spray pyrolysis is most popular today for the large area thin film formation pray solution result directly into oxide formation it has number of advantages: 1) Doping is easily as required amount of dopant is easy as required amount of Dopant can be added by mixing proper amount of solution of dopant. 2) Deposition in the moderate temperature range 150^0C to 500^0C is possible. 3) There is no restriction on the size and surface morphology of the substrate. 4) It is possible to prepare multilayer or Multi-compositional films.

In the present work, spray pyrolysis setup will be uses to prepare thin films of Nickel oxide. The one fourth of Earth inhabitant lack access to electricity with little and no change of outlook since over forty years now: 1) Several developing countries in Africa and other are still struggling to deliver affordable and stable electricity. 2) Renewable energy is a visible solution to ending the global electricity problem as it exceeds world electricity demand. 3) The properties of spray deposited film depending on the substrate, substrate temperature, spray rate and droplet size. 4) Droplet size depending on the spray rate nozzle diameter and carrier gas pressure. 5) Inorganic semiconducting materials are low cost, environmentally friendly and visible source of solar cell fabrication nanostructure metal oxide film had generated. They are used in detector, solar sales, gas sensing, semiconductor device, laser material, thermoelectric device, and optoelectronic device.

Recently, Transition metal oxides (TMOs) have garnered significant interest in basic research due to their various physical characteristics, applications in microelectronics and nanotechnology, materials science, and renewable energy [1–4]. They were employed as Li-ion battery electrode material [7], smart windows [6], and light-emitting diodes (LEDs) [5].

These metal oxides can be metallic or semiconducting, such as ZnO, TiO_2, NiO, Fe_2O_3, doped γ-Fe_2O_3, and Cr_2O_3 [8]. Nickel oxide (NiO) has drawn a lot of attention because of its exceptional chemical stability. It was a preferred contender due to its optical, electrical, and magnetic qualities in addition to its inexpensive cost and high specific capacitance [9]. With a NaCl-type structure, NiO is a crucial VIII–VI semiconductor [10]. Its broad band gap is between 3.6 and 4.0 eV [11]. The defect structure of nonstoichiometric nickel oxide makes it a suitable p-type semiconductor [12]. The formation of nickel vacancies and interstitial oxygen atoms in their structures may be the cause of the weak resistivity seen in NiO thin films [13, 14].

Literature review in the subject:

K.O. Koba, A. C. Elka -Ebola, F. L. Inambao (2017) were reported that, the effect of Nio film deposited using the spray pyrolysis techniques (SPT) physical and chemical method can be deposited nickel oxide film. It gives high product purity for metallic and non-metallic material deposition nickel chloride, nickel acetate, nickel nitrate, nickel hydroxide, nickel sulphate, nickel format are the deposition of NiO thin film. Nickel chloride and nickel acetate are most used and highly available precursor Nickel oxide film are p-type semiconductor and possesses direct band gap suitable for various application. The wide band gap is in the range of 3.25 to 4.00 eV

Chobani (2022): In this study the effect of looping on the Alpha-Fe_2O_3 properties. In this the thin layer of pure alpha Fe_2o_3 and Aluminium doped with spray pyrolysis method. The structure of morphological and optical properties of the prepared film from different percentage 2%, 4%, 6% ,8%, and 10% using x-ray diffraction, FT-IR, and UV. Structural characterization from x-ray diffractograms confirm the formation of Alpha Fe_2o_3.It has rhombihederal structure with

strong orientation study of transmittance spectra in UV-visible range 550 to 850 nm. It shows high transparency of thin layers and increases in direct band gap energy from 2.59 to 2.78 eV.

U. Cinder, Z. Topalian (2020): In the study was investigated nanocrystalline nanoporous NiO was a gas sensor and it is application. X-ray diffractometry it shows that film has face cantered cubic structure and scanning electron microscopy, x-ray photo electron spectroscopy, shows that Ni^{3+} and they state become less heat treatment in air x-ray absorption fine Structure analysis of the local atomic structure. Several techniques demonstrated that grain growth remained modest for annealing temperature as high as 400 ^{0}C for 1700nm thick film.

Yehya M. Abdul-Hussein (2019) have prepared that the doped nickel oxide and aluminium doped thin films were prepared by spray pyrolysis techniques from a hydrate salt solution of Nickel chloride. The structural morphological and sensing properties of the prepared of film have been studied x-ray diffraction investigation shows a polycrystalline phase with cubic crystalline structure. The morphology of the surface sample of thin film was investigated by atomic force microscopy (AFM).the sensing properties of prepared Nickel oxide film shows that the sensitivity to CO gas increased with changing aluminium doping

A. BagheriKhatib ani (2014): In this study was explained by application of aluminium and Nickel oxide in various field in solar energy conversions technology encouraged us to study physical properties of material. The deposition of the thin films on the glass substrate by SPM using x-ray diffraction (XRD), Scanning electron microscopy and UV-visible spectrophotometry. Different optical quantities such as optical band gaps, refractive index, extinction coefficient, dielectric constant, volume and surface energy loss function and Optical conductivity we are determined. With this paper for different Nickel to aluminium ratio from 20/60 to 80/20 ratio at specific substrate temperature 300^{0}C.

Firdous Shaker Ahmed (2023): In this study reported that the Nickel oxide and aluminium films were fabricated chemical spray pyrolysis techniques. XRD indicates a polycrystalline structure and dominant direction at (012) the grain size raised from 11.55nm to 213.14nm as aluminium content increment whereas the dislocation density parameter decreases from 74.96 to 57.25 while decreasing from 30.01 to 26.37.theAFM images shows that the particle size (T_p) of the deposited films was in the domain of (70.03 to 42.64nm) with increases doping from 1% vol to 3% vol Al average surface roughness. R_a values was decreases from 6.88to 2.22nm and RMS value shows that decreases from 7.74 to 3.22 nm with aluminium doping.

Research of hypothesis

- To study the growth of metal oxide such as undoped Nio, Fe and Al doped NiO in thin film form.
- To characterize undoped NiO, Fe and Al doped NiO thin films for structural, morphological, composition and electrical properties.
- To study gas properties of Fe and Al dopped NiO thin film will be investigated.
- To study growth of dopant on the properties of undoped NiO, Fe and Al with NiO thin films on the gas sensing.

Research methodology

Thin films deposition: In recent years, extensive efforts have been made in the preparation, characterization and application of metal oxides thin films. Thin film deposited by various techniques such as electrochemical deposition. Pulsed laser deposition, sol gel spin coating methods, and Chemical spray pyrolysis. In the present study, we propose to use spray pyrolysis technique for preparing pure and doped NiO thin film.

Application/ importance

- Gas sensors are devices that can detect the presence and concentration of gases in each environment. They are used in many industries and applications, including:
- Coal mines: Gas sensors are used to monitor the presence of gases in coal mines.
- Petroleum: Gas sensors are used in petroleum industries.
- Chemical plants: Gas sensors are used to detect leaks in chemical plants.
- Food companies: Gas sensors are used to ensure product quality in food companies.
- Vehicles: Gas sensors are used to determine exhaust gas in vehicles.
- Gas sensors can detect combustible, flammable, toxic gases, or oxygen consumption. They are important because they provide early warnings about hazardous gases, which allow people and industries to take action to prevent accidents and disasters. There are several types of gas sensors, including: Electrochemical gas sensors: These sensors use an electrochemical reaction to detect and measure the presence of gases. Metal oxide gas sensors: These sensors are widely used in industry for a variety of applications. Catalytic diffusion sensors: These sensors are the most widely used devices for detecting combustible gases and vapours.

Chapter scheme

- Chapter 1: -Introduction.
- Chapter 2: -Experiment and characterization techniques.
- Chapter 3: -Result and analysis of Fe doped NiO thin films.
- Chapter 4: -Result and analysis of Al doped NiO thin films.
- Chapter 5: -Conclusion and scope for future.

Motivation

In comparison to other transition metal oxides (such as SnO_2, TiO_2, and NiO), the synthesis and characterisation of NiO thin films is the least investigated, making it an appealing target

for research. Furthermore, one of the most essential approaches to change the material characteristics is to dope semiconductor nanoparticles with impurity metal ions. NiO thin films are good material for gas sensing. NiO can respond well to analytes like CO and H_2 in both dry and humid condition. NiO based gas sensors are highly repeatable and low cost as well as environmentally friendly. This has led me to study Nickel Oxide.

Plan of work

1. Plan of work in first year: - During the first-year we will do In the first year we will do literature survey on Fe and Al doped NiO thin films related to gas sensing applications. The literature includes collection of Journals, Books and some research papers related to the research work will be completed. Further we will place order for the chemicals which will use for the preparation of thin films. The efforts have been taken for the preparation of good quality undoped NiO and Fe and Al film thin by using spray pyrolysis techniques.

2. Plan of work in second year: - In second year the undoped NiO and Fe and Al doped NiO thin films will be characterized by various techniques XRD,SEM, FESEM, AFM, TEM and EDAX in this will be study the structural compositional and morphological properties. The performance of Undoped NiO and Fe and Al doped NiO thin films in gas sensing at various parameter such as scan rate, specific gas, stability cycles, and potential range. Thin film study on optical properties by using UV-spectrometer at least two progresses report are sent during the year. Two research paper to be reputed journal at the end of year.

3. Plan of work in Third year: - In the last year we will be prepared research papers to send them for the publication in reputed journals. The outcome of our research work will be present in national and international seminars and conferences this will be done final synopsis. Further we will submit the final thesis of the proposed work for doctoral degree.

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